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ABSTRACT

A review of research on the effects of aging on motor performance provided evidence that age-induced changes within the central nervous system, particularly in the functioning of the non-dominant cortical hemisphere, result in diminished fluid abilities. The loss was most clearly manifested behaviorally as a decreased capacity to perform high-speed, extrinsically-paced motor skills. A study assessed the effects of aging on the performance of intrinsically- and extrinsically-paced motor skills. Seventy-nine subjects (58 females and 21 males) were divided into three groups based on age: 60-65; 65-70; and over 70. Four criterion tasks were assigned: (1) pursuit rotor tracking; (2) mirror tracing; (3) visual choice reaction time; and (4) limb positioning. No significant differences in performance were observed among the three age groups on any of the tasks. There were significant differences between males and females for rotary pursuit tracking at all speeds. There were no significant differences between males and females on the other three tasks. There were no significant interaction effects between age and sex for any of the criterion measures. (JD)

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THE EFFECTS OF AGING ON MOTOR PERFORMANCE

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The study of motor skill acquisition must account for interactions among factors of task taxonomy, conditions of practice, and individual differences in age, sex, and basic ability level for any experimental population. These interactions are particularly critical when studying the effects of aging on motor learning. Despite intensive research, the study of aging and motor performance is confounded because certain fundamental issues which pertain to motor learning itself remain largely unanswered. Paramount among these issues are the questions of whether motor learning is best facilitated by massed or distributed practice and what serial order of learning will best insure positive transfer to each succeeding step. In addition to these general considerations, there are four major areas of concern with particular relevance to the study of aging and motor performance. These are: 1) the role of central versus peripheral neurological factors in aging; 2) the role of fluid and crystallized ability factors; 3) overall physical fitness level of the learner, and; 4) the taxonomical characteristics of the criterion (particularly speed).

Neurophysiological Factors

Welford contends that a knowledge of the structure of the nervous system can serve as a guide for research concerning its functional ramifications in the mediation of behavior. There is controversy as to whether the observed behavioral changes which accompany the aging process, particularly slowed reaction time, result form a decline of peripheral as opposed to central neurological function. Initial findings tended to support the former position. However, in the case of

motor activities, speed is determined by central neurological control mechanisms rather than by the maximum rate at which the muscles can contract. (1) Birren and Botwinick write that the rate of conduction by peripheral nerves accounts for only a small fraction of increased response time with age. (2) Welford presents four major theoretical arguments to account for the central factors which underlie slowing of response with age: a decrease in the number of brain cells; an increase in random neurological activity; increased aftereffects of neural activity, and; increased activation and arousal.

All of these factors are functionally interrelated in that they result in an unfavorable increase in the signal to noise ratio of the system. There is more spurious activity in relation to directed activity. Increased neural aftereffects are most functionally significant in the performance of rapidly-paced, continuous tasks. Neural signals from the prior response, still present when the commands for the succeeding one are elicited, result in interference and inaccurate performance. Neural aftereffects spontaneously dissipate during the interresponse interval, and performance upon activities which are temporally distributed is less adversely affected than that of highly-speeded, continuous tasks. This factor is critical in the slowing of response with aging and is of prime importance in developing compensatory response strategies.

Birren writes that although individual differences in speeded performance vary from task to task for youthful subjects, there is a general slowing of response on all types of tasks in the aged. He

hypothsizes this phenomenon to result from a loss of RNA in all cells of the body due to decreased stimulation. He attributes this overall decline to changes within the central nervous system, particularly in the functions of the basal ganglia and reticular formation. (3) Botwinick writes that although peripheral nerve transmission speeds are greater in the aged, this factor, in and of itself, constitutes a relatively minor element in the total time needed to execute voluntary reactions when compared to the cumulative effects of synaptic delays within the central nervous system. (4) Birren writes that the decline in motor performance during late maturity is the result of a decrease in the number of neurons and receptors in the central nervous system. Severe biological constraints upon perceptual and motor performance due to these changes are usually not pronounced until after the age of 70. (5)

Further evidence supporting the position that decline in performance due to aging results from changes within the central nervous system itself is provided by Malone and Szoke. They write that the observed atrophy and weight loss of the brain due to aging tends to be most pronounced within the cortical association areas, structures critical to the processing of sensory information. (6) Goldstein and Shelly observed that the minor cortical hemisphere is more adversely affected by aging than is the major hemisphere. (The former is central in the processing of temporal and spatial information, while the latter is critical to verbal and quantitative activities. (7) Shelton et al. employed verbal and visuospatial learning tasks in which the structure and task requirements were similar and found no evidence to support the laterality

effect with aging. Systematic performance decrements in both verbal and visuospatial learning were found for subjects 30 through 70. The authors note that when measures are employed which differ in respect to structure and level of difficulty, age associated differences are observed and the laterality-aging hypothesis is substantiated. (8)

Benton et al. administered nine neuropsychological tests assessing temporal orientation, short-term memory, language functions, and visuoperceptive capacity to subjects ranging in age from 65 to 84 years. There was little difference in cognitive performance between the older and younger subjects. The largest aging decline was observed on tests of short-term visual memory, serial digit learning, and facial recognition. The authors contend that their findings do not support the hypothesis that the minor hemisphere ages more quickly than the major, since performance on the judgment of line direction measure (a test closely related to minor hemisphere function) was less adversely affected by aging than performance on the other tasks employed. There was comparatively little observed overall performance decrement with age until beyond the eightieth year. These findings may be due in part to the fact that none of the measures employed stressed speeded response. (9)

Ability Factors

Noble writes that age is a biological factor that interacts with practice variables in the learning and performance of motor skills. This interaction is confounded, however, by the nature of the learning task and the individual differences of the subject. (10) Cattell hypothesized two forms of intellectual capacity: fluid and crystallized. Fluid in-

telligence is linked to biolcgical factors and directly reflects the functioning of the neurological structures. It grows steadily throughout the period of physiological maturation, reaching its peak in late adolescence and early adulthood, and then declines with age. Fluid intelligence is deemed critical to perceiving relationships, forming concepts, reasoning abstractly, and solving problems. It is essential in eliciting appropriate behavioral adaptations in response to rapidly changing environmental conditions (speeded responses). Crystallized intelligence, in contrast, constitutes a function of collective learning via cultural assimilation, and is strongly influenced by formal and informal educational factors. It is believed to increase steadily, barring pathological impairments, throughout the adult life span. (11) Horn contends that much of the controversy surrounding the effects of aging on human performance results from the failure to distinguish between these two capacities, which are separate and independent yet positively related. Variables which measure crystallized intelligence show little or no aging decline, while performance variables which reflect fluid intelligence indicate significant declines with aging. (12)

Cunningham et al. write that fluid and crystallized intelligence represent different behavioral factors, and that the acquisition of the latter is dependent upon the presence of the former. (Fluid intelligence is indicative of the underlying neurological capacity.) The authors observed that the two factors were highly correlated among adolescents, but this correlation decreased significantly for subjects over 60. This substantiated their contention that the acquisition of

skills which rely upon crystallized capacities is not affected by aging in the same way as is the learning of skills which entail fluid abilities. (13) Hayslip and Sterns observed that while fluid and crystallized abilities are differentially affected by aging, the degree of difference is dependent upon task-specific factors. The authors discuss two classes of tasks, type C and type O. Execution of the former entails the application of prior knowledge and experience, while the latter tasks involve spontaneous, novel response patterns. The greatest aging decrement is observed in the performance of highly speeded, type O tasks. (14) Blieszner et al. write that the observed deficit in fluid abilities with aging may result from experiential as well as physiological factors. They contend that the capacity to benefit from training is maintained throughout the adult life span and that the decline in fluid ability factors with age can be lessened through the application of the appropriate intervention strategies. (15)

Physical Fitness

Aging affects a number of parameters that are related to overall fitness. Clarkson et al. observed a decrease in both static and dynamic strength attributable to a decline in the ratio of fast- to slow-twitch muscle fibers. (The former are critical to strength, while the latter are central to endurance-type activities.) The authors contend that this change may adversely affect the number of functional motor units, resulting in a diminished capacity for skilled performance. (16) Farrar et al. write that there is a decline in maximal oxygen consumption with aging that is attributable to decreases in cardiac output, muscle

mass, and oxidative capacity per gram of muscle. These changes are linked to a decrease in mitochondrial protein. (17) Spirduso and Farrar contend that elderly individuals who are physically fit demonstrate significantly faster neuromuscular responses than do sedentary individuals of the same age. The authors observed that exercise training may contribute to the maintenance of both reflex-like and operantly conditioned behavior in aged rats. (18) Elsayed et al. studied the effects of aging on performance in subjects of high and low physical fitness. Regardless of age, the highly fit group had a significantly higher total fluid intelligence score than the low fitness group. However, the younger group had a significantly higher total fluid intelligence score than the older group where fitness was not a factor. (19)

Response Time and Task Taxonomy

Milligan et al. write that the commonly observed psychomotor decrement in the aged may be related to changes in the central nervous system, but that social and psychological factors may also play a role. The authors observed that even the most highly motivated subjects were able to perform at optimum level only on those tasks perceived as easy to accomplish. Task difficulty is believed to constitute an important variable which should be studied in future research on the psychological determinants of behavioral deficits in the aged. (20)

Gottsdanker observed that there is a marked age difference in simple reaction time when performance is enhanced by the subject's temporal control of preparation. Young subjects outperformed elderly

subjects only when a long, constant preparatory interval was given. When such preparatory activity was either severely limited or non-existent, age differences in simple reaction time were minimal. (21) Salthouse and Somberg write that older subjects require more time than do young subjects for their accuracy to improve beyond a chance level on speeded tasks. Beyond this point, the rate at which their accuracy increases is equal to that of younger subjects. (22) Corpolongo and Salmon employed four simple reaction time tasks and observed that elderly subjects had little difficulty making judgments in terms of the number of response choices. However, when the information for a judgment did not have direct relevance to the decision, it was difficult for elderly persons to use this information adequately. (23)

Noble et al. utilized a discrimination-reaction time task employing subjects ranging in age from 8 to 87 years. There was a significant interaction between age and performance in that older individuals performed more poorly than younger persons. (24) Nebes writes that the decrease in response speed usually found to occur with advancing age is felt by many investigators to be a phenomenon common to all speeded tasks, regardless of the exact nature of the sensory stimulus or motor response involved. Nebes observed, however, that the type of response the subject made determined whether or not an age difference existed in simple reaction time to a visual stimulus. When subjects responded manually by releasing a key, the usual age decrement in response latency was found. When the same subjects responded vocally by saying a word, there was no significant age difference in reaction time. The author

contends that these findings indicate that the slowing of psychomotor latency with age is not a general phenomenon, but may be limited instead to certain neural systems. (25) This contention is substantiated in part by the findings of Wallace et al., which indicate that simple reflexive tasks show little or no change as a function of aging in rats.(26)

In addition to its dependence upon fluid and crystallized capacities, psychomotor performance in the aged entails factors of spatial and temporal memory, which are themselves dependent upon both automatic and effortful information processing. Perlmutter et al. write that automatic processing functions tend to decline with age, while effortful memory functions, which entail the actual utilization of cognitive capacities, are less adversely affected. This observation may be due to the overall slowing of response time in the aged since automatic information processing is highly speeded in nature. (27)

Further evidence of the decline in motor efficiency with age is provided by Danziger and Botwinick, who observed that younger adults were better able to discriminate the difference between a set of weights than older adults. Among older adults, however, men discriminated better than women. (28) Ammons and Ammons employed a pursuit rotor tracking task and observed a steady decrease in proficiency and an increase in the time required to overcome warm-up decrement as the age of the subjects increased beyond 39 years. (29)

Summary

Predicated upon evidence from neurophysiological and behavioral research, it can be concluded that age-induced changes within the cen-

tral nervous system, particularly in the functioning of the non-dominant cortical hemisphere, result in diminished fluid abilities. This loss is most clearly manifested behaviorally as a decreased capacity to perform highly-speeded, extrinsically-paced motor tasks. The application of appropriate intervention techniques and the maintenance of overall physical fitness can lessen the degree of this decline.

This study will assess the effects of aging on the performance of intrinsically- and extrinsically-paced motor skills. It is hypothesized that the most significant aging decrement will be observed for the pursuit rotor tracking task under massed practice conditions at high speed (60 RPM), and that these differences will occur regardless of sex. It is further hypothesized that significant aging decrements will be observed for visual choice reaction time, mirror tracing, and limb positioning, and that these differences, too, will occur regardless of sex.

METHOD

Seventy-nine volunteer subjects (58 females and 21 males), ranging in age from 60 to 80, were recruited from the Brooklyn College vivinity and from classes and programs offered by Brooklyn College to senior citizens. The subjects were divided into three groups based on age: 60-65 (n = 8); 65-70 (n = 24), and over 70 (n = 47). All subjects were tested on four criterion tasks: 1) pursuit rotor tracking; 2) mirror tracing; 3) visual choice reaction time, and; 4) limb positioning.

The rotary pursuit task was varied along two parameters, temporal distribution and speed. A photoelectric rotary pursuit apparatus was employed, and the score for each subject was determined by the total time on target under each practice condition. The massed condition entailed a continuous, 60-second practice session, while the distributed condition involved two 30-second practice periods separated by a 30-second rest period. The three criterion speeds employed were: low (15 RPM); medium (30 RPM), and; high (60 RPM). Each subject was tested at all three criterion speeds under both massed and distributed practice conditions.

The mirror tracing task employed an automatic scoring mirror trace apparatus, and the score for each subject was based on the number of errors. This task was subject-paced, but a maximum time limit of 5 minutes was set.

The visual choice reaction time task employed a four-choice visual reaction time apparatus. The subject was instructed to position himself comfortably with his hand in close proximity to the response key-

board. Each subject was given ten trials; his score was based upon the time elapsed from the onset of the stimulus to the elicitation of the response (pressing the appropriate button).

The limb positioning task employed a kinesthesiometer. The experimenter rotated the subject's arm a given number of degrees and then returned it to the starting point. The subject then had to reposition the arm as closely as possible to the criterion position. Subjects could not see the apparatus; their score was determined by the absolute error between the criterion position and the one actually attained. Each subject was given five trials.

RESULTS AND DISCUSSION

No significant differences in performance were observed among the three age groups on any of the criterion tasks. There were significant differences between males and females for rotary pursuit tracking at all speeds and under both massed and distributed practice conditions. These differences tended to be greater under distributed practice conditions and at higher speeds. (See Tables 1 and 2.) There were no significant differences between males and females on visual choice reaction time, mirror tracing, and limb positioning. There were no significant interaction effects between age and sex for any of the criterion measures.

TABLE 1

UNIVARIATE MEANS, STANDARD DEVIATIONS, AND UPPER AND LOWER SCORE LIMITS FOR ROTARY PURSUIT TRACKING

	15 RPM		30 RPM		60 RPM	
	Massed	Dist.	Massed	Dist.	Massed	Dist
Female:						
Mean	30.29	34.60	15.82	18.14	1.42	2.15
SD	7.80	8.85	6.35	6.58	1.25	1.57
High	47.68	50.44	33.57	33.84	4.96	7.08
Low	9.84	5.89	1.34	5.05	0.24	0.35
Male:						
Mean	34.65	41.25	19.13	22.25	2.99	4.29
SD	9.61	9.26	6.37	7.19	1.96	2.28
High	53.65	55.35	30.53	34.31	6.68	8.52
Low	19.61	19.39	6.96	5.98	0.03	0.40

TABLE 2

ANOVA FOR AGE, SEX, AND ROTARY PURSUIT SKILL

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Massed Practice: 15 RPM					
Main effects	619.384	3	206.661	3.037	0.034
Sex	307.557	1	307.557	4.519	0.037
Age	327.522	2	163.761	2.406	0.097
Two-way interactions	25.197	2	12.598	0.185	0.831
Sex and age	25.197	2	12.598	0.185	0.831
Explained (treatment)	645.184	5	129.037	1.896	0.105
Residual (error)	4967.828	73	68.052		
Total	5613.012	78	71.962		
Massed Practice: 30 RPM					
Main effects	339.683	3	113.228	2.835	0.044
Sex	178.654	1	178.654	4.474	0.038
Age	170.800	2	85.400	2.138	0.125
Two-way interactions	23.404	2	11.702	0.293	0.747
Sex and age	23.404	2	11.702	0.293	0.747
Explained (treatment)	363.087	5	72.617	1.818	0.120
Residual (error)	2915.275	73	39.935		
Total	3278.361	78	42.030		
Massed Practice: 60 RPM					
Main effects	40.538	3	13.513	6.070	0.001
Sex	35.879	1	35.879	16.116	0.000
Age	2.564	2	1.282	0.576	0.565
Two-way interactions	1.719	2	0.859	0.386	0.681
Sex and age	1.719	2	0.859	0.386	0.681
Explained (treatment)	42.257	5	8.451	3.796	0.004
Residual (error)	162.516	73	2.226		
Total	204.773	78	2.625		

TABLE 2 (continued)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Distributed Practice: 15 RPM					
Main effects	844.674	3	281.558	3.426	0.021
Sex	719.209	1	719.209	8.751	0.004
Age	171.301	2	85.650	1.042	0.358
Two-way interactions	4.647	2	2.324	0.028	0.972
Sex and age	4.647	2	2.324	0.028	0.972
Explained (treatment)	849.324	5	169.865	2.067	0.079
Residual (error)	5999.590	73	82.186		
Total	6848.914	78	87.807		
Distributed Practice: 30 RPM					
Main effects	402.635	3	134.212	2.942	0.039
Sex	278.506	1	278.506	6.105	0.016
Age	141.670	2	70.835	1.553	0.219
Two-way interactions	26.900	2	13.450	0.295	0.746
Sex and age	26.900	2	13.450	0.295	0.746
Explained (treatment)	429.535	5	85.907	1.883	0.108
Residual (error)	330.134	73	45.618		
Total	3759.669	78	48.201		
Distributed Practice: 60 RPM					
Main effects	72.790	3	24.263	7.329	0.000
Sex	67.931	1	67.931	20.520	0.000
Age	2.085	2	1.043	0.315	0.731
Two-way interactions	1.824	2	0.912	0.275	0.760
Sex and age	1.824	2	0.912	0.275	0.760
Explained (treatment)	74.614	5	14.923	4.508	0.001
Residual (error)	241.664	73	3.310		
Total	316.278	78	4.055		

The lack of significant differences among the three age groups may be attributable to two factors: 1) chronological age alone is a relatively insignificant index of motor skill level, and 2) the taxonomy of the criterion task constitutes a critical element in the outcome of any study. The significant differences between males and females for the pursuit rotor tracking tasks may be attributable to factors of differing societal expectation for men and women. Although these expectations have been radically altered in recent years, the subjects in this study, all over 60 years of age, were overwhelmingly conditioned to accept the "traditional" sex roles for men and women. Many of the female subjects had never driven an automobile and were clearly uncomfortable performing an extrinsically paced task, particularly under highly speeded conditions. Success in this activity was dependent upon a more agressive pattern of response than were the other criterion tasks. Many of the female subjects were intimidated by the mechanical nature of the pursuit rotor and performed poorly under all speeds and under all conditions of practice.

Further research is needed in the area of aging and motor performance, particularly in terms of the interactions between the individual differences of the learner and the taxonomical characteristics of the learning task. This study showed no significant interactions for age and sex in the performance of tasks which involved factors of spatial ability, information-processing rate, and kinesthetic ability. However, there were highly significant differences between males and females in the performance of a task which required responding to an extrinsically paced situation.

The lack of significant differences among the three age groups employed in this study is indicative of the weakness of chronological age alone as a valid classification index for the older adult. It is recommended that further research be conducted concerning the interactions between individual differences and task taxonomy in the study of skill acquisition in the aged. In order to achieve these ends, it is necessary to establish valid and reliable developmental indices exclusive of chronological age.

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